

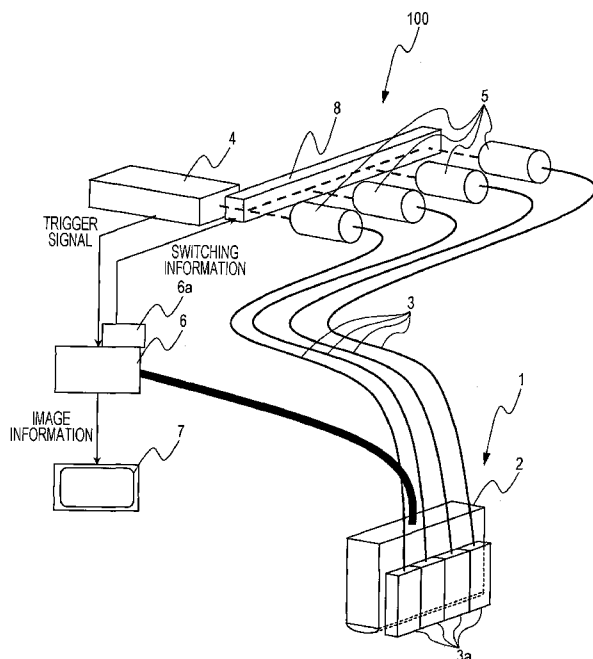


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[Continued on next page]

(54) **Title:** SUBJECT INFORMATION ACQUISITION APPARATUS

FIG. 1



(57) **Abstract:** The present invention relates to a subject information acquisition apparatus for increasing intensity of photoacoustic signals and improving SNR without increasing scale of the circuit board of the processing apparatus and without increasing the output of the light source. The irradiation position of the illumination light is changed while the substantial total light quantity to the subject is maintained and the light quantity in the irradiated area does not exceed the maximum permissible exposure of skin. The processing apparatus determines the irradiation position and the receiving aperture of the probe and drives the switching apparatus.



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DESCRIPTION

SUBJECT INFORMATION ACQUISITION APPARATUS

Technical Field

[0001] The present invention relates to a subject information acquisition apparatus for irradiating illumination light to a subject and imaging ultrasonic waves emitted from the subject.

Background Art

[0002] Photoacoustic tomography (hereinafter referred to as PAT) attracts attention as a method for specifically imaging angiogenesis caused by cancer. The PAT is a technique for irradiating illumination light (near-infrared light) to a subject and receiving photoacoustic waves generated from the inside of the subject by an ultrasonic probe to make an image. Regarding the PAT, Fig. 9 shows a schematic diagram of a photoacoustic apparatus described in NPL 1. In Fig. 9, a photoacoustic probe 101 includes a probe 102 having 128 elements (transducers) that receive photoacoustic waves generated from the subject and an illumination optical system 105 for irradiating illumination light to the subject. An ultrasonic apparatus 100 is a system equipped with 32 receiving channels and a processing apparatus 106 of the ultrasonic apparatus 100 converts the

photoacoustic waves received by the probe 102 into an image. At this time, the illumination light is emitted from a laser light source 104 on the basis of a trigger signal from a function generator and the probe 102 acquires photoacoustic waves in synchronization with the illumination light.

Citation List

Non Patent Literature

[0003] NPL 1 S. Park et al., Beamforming for photoacoustic imaging using linear array transducer, 2007 IEEE Ultrasonics Symposium, 2007.

SUMMARY OF INVENTION

Technical Problem

[0004] However, the conventional technique has a problem as described below.

[0005] NPL 1 uses the ultrasonic apparatus 100 equipped with 32 receiving channels and a linear probe (probe 102) equipped with 128 elements to acquire a PAT image and an ultrasonic image. In other words, information is acquired from the 32 elements at the same time, and an image is acquired on the basis of the information. Therefore, when a PAT image is acquired, the number of channels through which information can be received at the same time is smaller than the number of the elements of the probe 102, so that an aperture for acquiring a PAT image is small. Thus, when the information is converted into an image, the width of the

acquired image is small. On the other hand, if the number of channels (elements) through which information can be received at the same time is increased to enlarge the aperture for acquiring a PAT image, the circuit scale of the processing apparatus 106 is also increased.

[0006] Further, although the number of channels (elements) through which information can be received at the same time is 32, the illumination light is irradiated to all the elements (128 elements) adjacent to the probe 102.

Therefore, the illumination light for 96 elements that do not contribute to receiving information is wasted. An initial sound pressure p of photoacoustic wave can be represented as $p = \Gamma\mu\phi$ (Γ : Gruneisen coefficient, μ : absorption coefficient, ϕ : light quantity). Therefore, if the same quantity of illumination light is irradiated to the entire width of elements (128 elements) adjacent to the probe 102 and an aperture width of 32 elements, the initial sound pressure to the 32 element is four times larger than that to the 128 elements. This is because, when the illumination light is irradiate to the 128 elements, the light quantity ϕ to a tissue (light absorber) in the subject becomes about 1/4, so that the initial sound pressure p generated from the tissue becomes about 1/4. Therefore, signal intensity that can be received by the probe 102 decreases. If a light source 104 that emits a large

quantity of light is used (total light quantity is large), it is possible to increase the initial sound pressure of a photoacoustic signal. However, in this case, there is a problem that the size of the light source 104 increases and it is difficult to procure the light source 104.

[0007] The present invention has been made in view of the above problems in the background art.

[0008] The present invention provides a subject information acquisition apparatus that can improve SNR (signal noise ratio) by increasing intensity of photoacoustic signals without increasing scale of the circuit that performs receiving processing of the photoacoustic signals and without increasing the output of the light source.

Solution to Problem

[0009] The present invention provides a subject information acquisition apparatus including a light irradiation unit including a light source and an emitting end portion configured to emit light generated by the light source to a subject, an irradiation control unit configured to control irradiation of the subject with the light emitted from the emitting end portion of the light irradiation unit, a probe including a plurality of transducers configured to receive acoustic waves generated by the subject irradiated with the light from the light irradiation unit and output

electrical signals, a receiving unit configured to receive the electrical signals from a part of transducers of the plurality of transducers included in the probe, and a probe control unit configured to switch a part of transducers that output the electrical signals to be received by the receiving unit to another part of transducers. The irradiation control unit controls a position of the emitting end portion with respect to the subject so that a size of an irradiation area of the light to the subject is smaller than a size of the probe and the irradiation area corresponds to a position of the part of transducers while a quantity of the light emitted from the emitting end portion is maintained at a total light quantity of the light generated by the light source.

Advantageous Effects of Invention

[0010] According to the present invention, SNR is improved without increasing scale of the receiving unit and without increasing the output of the light source.

BRIEF DESCRIPTION OF DRAWINGS

[0011] Fig. 1 is a diagram for explaining an apparatus configuration of a first embodiment of the present invention.

[0012] Figs. 2A and 2B are diagrams for explaining a switching method of the first embodiment of the present invention.

[0013] Figs. 3A, 3B, and 3C are diagrams for explaining a

configuration of a switching apparatus of the first embodiment of the present invention.

[0014] Figs. 4A and 4B are diagrams for explaining another configuration of the switching apparatus of the first embodiment of the present invention.

[0015] Fig. 5 is a diagram for explaining an apparatus configuration of a second embodiment of the present invention.

[0016] Figs. 6A and 6B are diagrams for explaining a switching method and a configuration of the second embodiment of the present invention.

[0017] Fig. 7 is a diagram for explaining another configuration of a switching apparatus of the second embodiment of the present invention.

[0018] Fig. 8 is a diagram for explaining an apparatus configuration of a third embodiment of the present invention.

[0019] Fig. 9 is a diagram for explaining a background art.

Description of Embodiments

[0020] Embodiments of the present invention will be described with reference to the drawings. Fig. 1A is a schematic diagram of a photoacoustic apparatus 100, which is a hand-held type subject information acquisition apparatus. The photoacoustic apparatus 100, which is a subject information acquisition apparatus, includes a light irradiation unit, an irradiation control unit that controls

light emitted from the light irradiation unit, a probe including a plurality of transducers that receive acoustic waves generated from a subject which is irradiated with the light, a receiving unit that receives electrical signals generated by the transducers included in the probe, and a probe control unit that switches combinations of transducers that output electrical signals among the plurality of transducers included in the probe. Each unit will be described below in detail.

[0021] The light irradiation unit includes a light source 4 that generates illumination light and an emitting end 3a which is an emitting end portion for emitting the illumination light generated by the light source 4 to a subject not shown in the drawings. In an embodiment shown in Fig. 1, the emitting end portion is an end portion 3a of a bundled fiber 3. In the embodiment shown in Fig. 1, an illumination optical system 5 is located between the light source 4 and the emitting end 3a which is the emitting end portion.

[0022] The irradiation control unit controls irradiation of the subject with the light emitted from the emitting end portion of the light irradiation unit and includes a switching apparatus 8 and a control apparatus 6a that controls the switching apparatus 8 in the embodiment shown in Fig. 1. The switching apparatus 8 is provided between

the light source 4 and the illumination optical system 5 and switches incidence of the light generated by the light source 4 onto the illumination optical system 5. The operation of the switching apparatus 8 is performed on the basis of switching information from the control apparatus 6a.

[0023] The probe 2 includes a plurality of transducers 2a (see Fig. 2A described later) inside the probe 2. The transducer 2a receives the acoustic waves generated from the subject which is irradiated with the light from the emitting end 3a, which is the emitting end portion of the light irradiation unit, and outputs an electrical signal. In the present invention, a relationship between the probe 2 or the transducer 2a included in the probe 2 and the emitting end 3a which is the emitting end portion described above is one of the features of the present invention, so that the probe 2 and the emitting end 3a may be collectively referred to as a photoacoustic probe 1 in the description below.

[0024] The processing apparatus 6, which is a receiving unit, receives an electrical signal from a part of the transducers 2a of the plurality of transducers 2a included in the probe 2. In the embodiment, the processing apparatus 6, which is the receiving unit, performs various processing, such as amplification processing, digital conversion processing, and image reconstruction processing, on an electrical signal based on the acoustic waves received by

the transducers 2a included in the probe 2, and displays image information on a monitor 7.

[0025] The probe control unit switches a part of transducers that outputs the electrical signal to be received by the receiving unit to another part of transducers, and includes the control apparatus 6a described above in the embodiment shown in Fig. 1. In other words, in the embodiment shown in Fig. 1, the control apparatus 6a doubles as a part of the illumination control unit and the probe control unit.

[0026] In the embodiment, the switching apparatus 8, which is the irradiation control unit, and the control apparatus 6a, which controls the switching apparatus 8, perform control so that the size of a light irradiation area to the subject not shown in the drawings is smaller than the size of the probe 2 while maintaining the quantity of the light emitted from the emitting end 3a, which is the emitting end portion, at the total light quantity of the light generated by the light source 4. Further, the switching apparatus 8 and the control apparatus 6a control the position of the emitting end 3a, which is the emitting end portion, with respect to the subject so that the light irradiation area corresponds to a position of a part of the transducers that output the electrical signal to be received by the receiving unit. Here, the light irradiation area to the subject is

equal to the area of the emitting end 3a.

[0027] As described above, in the embodiment, the receiving unit receives an electrical signal from a part of the transducers 2a of the plurality of transducers 2a included in the probe 2, so that it is possible to acquire subject information without increasing circuit scale of the receiving unit.

[0028] Further, the probe control unit switches a part of the transducers 2a that outputs the electrical signal to be received by the receiving unit to another part of the transducers 2a. The irradiation control unit maintains the quantity of the light emitted from the emitting end portion at the total light quantity of the light generated by the light source 4. Further, the irradiation control unit controls the position of the emitting end portion with respect to the subject so that the size of the light irradiation area to the subject is smaller than the size of the probe 2 and the light irradiation area corresponds to the position of a part of the transducers that output the electrical signal to be received by the receiving unit. Thereby, the sound pressure of the photoacoustic waves can be increased and, as a result, the SNR can be improved without increasing the output of the light source 4. Therefore, it is possible to acquire acoustic waves while fully leveraging the size the probe 2.

[0029] Hereinafter, the present invention will be described with reference to embodiments.

First Embodiment

[0030] Regarding a first embodiment, a hand-held type photoacoustic apparatus will be described with reference to Fig. 1. A photoacoustic probe 1 includes a probe 2 that receives photoacoustic waves generated from the subject and an emitting end that emits illumination light of near-infrared light to the subject. As an example, the probe 2 is a linear probe and provided with a plurality of bundled fibers 3 connecting to the emitting end. The probe 2 includes a plurality of transducers 2a that receive photoacoustic waves and output an electrical signal (see Fig. 2A). Although Fig. 1 does not show the illumination optical system from the emitting end 3a of the bundled fibers to the subject, the subject may be directly irradiated from the emitting end 3a of the bundled fibers or an arbitrary optical system such as a diffuser panel may be provided. The illumination light may be guided to the subject by propagation through air using a combination of mirrors provided in a light shielding tube without using the bundled fibers 3. Further, although the emitting end 3a of the bundled fibers is shown on one side of the probe 2 in Fig. 1, it is not limited to this, and the emitting ends may be provided symmetrically with respect to the probe 2 to

sandwich the probe 2.

[0031] The near-infrared light is generated by the light source 4, formed into a beam by the illumination optical system 5, and emitted to the bundled fibers 3. As the light source 1, a pulse laser such as an Nd:YAG laser and an alexandrite laser is used. Also, a Ti:sa laser and an OPO laser which use Nd:YAG laser light as excitation light may be used.

[0032] There are a plurality of emitting ends 3a according to the number of bundled fibers on the side of the photoacoustic probe 1. The plurality of emitting ends 3a are provided adjacent to the probe 2. A substantial total light quantity of the illumination light generated from the light source 4 is propagated to an emitting end 3a of any one of the bundled fibers. In other words, the total light quantity of the light generated by the light source 4 is maintained and propagated to the emitting end 3a. The substantial total light quantity from the light source 4 mentioned here means that the total light quantity that can be irradiated is irradiated to only one position when acquiring one piece of photoacoustic data without branching the illumination light by a half mirror or the like to irradiate the illumination light to a plurality of irradiation positions. Therefore, even if the total light quantity is reduced due to attenuation and reflection of the

light being propagated or due to branches for measuring the light quantity or acquiring a trigger, such reduction of the total light quantity is ignored. Further, even when a near total light quantity from the light source 4 is irradiated from one irradiation position and a small quantity of illumination light is irradiated from the other irradiation positions, it is assumed that the substantial total light quantity from the light source 4 is irradiated from the one irradiation position.

[0033] The area of the emitting end 3a of the bundled fiber (the size of irradiation area to the subject) is determined by a product of a receiving aperture width (the number of aperture elements) and the depth in a direction perpendicular to the width. In the description below, the aperture width and the aperture (receiving aperture) will be mentioned. The aperture means a part of elements (a part of elements of the probe 2) that receive acoustic waves and output an electrical signal to the processing apparatus 6, which is the receiving unit. In other words, the aperture means a part of transducers that output an electrical signal to be received by the processing apparatus 6, which is the receiving unit. The depth of the area of the emitting end 3a is reduced according to the substantial total light quantity from the light source 4 so that the light quantity increases as much as possible within a range smaller than or

equal to the maximum permissible exposure (MPE) of skin. Thereby, the size of the photoacoustic waves for one time irradiation of the illumination light increases. The light irradiation area to the subject is equal to the area of the emitting end 3a. Fig. 1 shows a case in which the aperture width through which the photoacoustic waves can be acquired at once (the number of the aperture elements, it means a part of transducers of the plurality of transducers included in the probe) is $1/4$ of the entire width. Therefore, four emitting ends 3a of the bundled fibers are provided and the width of each emitting end corresponds to the aperture width. The number of divided light irradiation areas to the subject (the number of the emitting ends 3a of the bundled fibers) is not limited to four. The number of the emitting ends 3a can be determined according to an acquisition receiving aperture width (the number of the aperture elements) of the photoacoustic waves. For example, if the aperture width through which the photoacoustic waves can be acquired at once is a half of the entire width, the light irradiation area to the subject may be divided into two areas. The processing apparatus 6 acquires an electrical signal outputted from the elements of the transducers by using the elements of the transducers of the probe 2 adjacent to a switched irradiation position of the illumination light. The element of the probe 2 means a photoacoustic wave

receiving element including a transducer included in the probe 2. Normally, the element includes a plurality of transducers, so that the probe 2 includes a plurality of elements (photoacoustic wave receiving elements) including a plurality of transducers. The probe 2 outputs an electrical signal from a part of the elements to the processing apparatus 6, so that, as a result, the processing apparatus 6 receives an electrical signal from a part of transducers of the plurality of transducers included in the probe 2. However, in Fig. 2A described below, for ease of understanding the invention, the configuration and the drawing are simplified and one element corresponds to one transducer 2a.

[0034] Even when the number of elements of the probe 2 is 128 and the number of channels through which the processing apparatus 6 can acquire electrical signal is 32 (32 elements), the present embodiment may be applied by dividing the elements into smaller aperture widths (for example, 8 sets of 16 elements). This is suitable when the output of the light source 4 is low.

[0035] An output from a photodiode (not shown in the drawings) measured by branching a part of the illumination light is used as a trigger signal. When the trigger signal is inputted into the processing apparatus 6, the probe 2 acquires photoacoustic waves and outputs an electrical

signal (hereinafter may be referred to as an acoustic wave signal) based on the photoacoustic waves. The processing apparatus 6 performs amplification processing, digital conversion processing, and image reconstruction processing on the electrical signal, generates image information, and displays the image information on the monitor 7. The trigger signal is not limited to an output from the photodiode, but a method can be used in which light emission from the light source 4 and a trigger signal inputted into the processing apparatus are synchronized by a signal generator (function generator).

[0036] The switching apparatus 8, which is a part of the irradiation control unit, is provided to change the irradiation position of the illumination light. In Fig. 1, the switching apparatus 8 is provided between the light source 4 and the illumination optical systems 5 and switches light entering the illumination optical system 5 on the basis of the switching information from the control apparatus 6a which is a part of the irradiation control unit. Therefore, the substantial total light quantity from the light source 4 irradiated from the emitting end 3a of each bundled fiber by switching is maintained to be constant. The control apparatus 6a selects an emitting end 3a of a bundled fiber adjacent to the receiving aperture of the probe 2 from a plurality of emitting ends 3a and operates

the switching apparatus 8 so that the illumination light from the light source 4 enters an illumination optical system 5 corresponding to the emitting end 3a of the bundled fiber. The arrangement order of the switching apparatus 8 and the illumination optical systems 5 may be changed and the opposite arrangement may be used.

[0037] Next, the control apparatus 6a that switches the irradiation position will be described with reference to Fig. 2. Fig. 2A is a front view of the photoacoustic probe 1. The probe 2 is a linear probe including a plurality of transducers 2a. The type of the probe 2 is not limited to the linear probe, but a convex probe can be used.

[0038] In Fig. 2A, the number of the receiving elements of the probe 2 is 128 channels and the number of channels through which the processing apparatus 6 can acquire electrical signals at once is 32. Specifically, the channels are divided into channel numbers of 0 to 31 (receiving aperture A), 32 to 63 (receiving aperture B), 64 to 95 (receiving aperture C), and 96 to 127 (receiving aperture D). The processing apparatus 6 sequentially receives electrical signals (photoacoustic signals) based on the photoacoustic waves sequentially in order of the receiving aperture A to the receiving aperture D.

[0039] Next, the control apparatus 6a will be described with reference to a timing chart in Fig. 2B. When the laser

emission of the light source 4 is 10 Hz, the emission interval is 100 ms. To receive the photoacoustic signals (electrical signals) by the elements of the receiving aperture A, the control apparatus 6a operates the switching unit 8 and irradiates the illumination light from the emitting end 3a of the bundled fiber adjacent to the elements of the receiving aperture A. The processing apparatus 6 acquires photoacoustic signals (electrical signals) by using the elements of the receiving aperture A in synchronization with the irradiation (in Fig. 2B, 30 μ s). In a time period between the laser emission and the next laser emission (in Fig. 2B, at a timing after 50 μ s from the timing when the laser is emitted), the control apparatus 6a operates the switching unit 8 so that the emitting end 3a of the bundled fiber adjacent to the elements of the receiving aperture B irradiates the illumination light. The processing apparatus 6 acquires photoacoustic signals (electrical signals) by using the elements of the receiving aperture B in synchronization with the irradiation. Similarly, in a time period between the laser emission and the next laser emission, the control apparatus 6a operates the switching unit 8 so that the emitting end 3a of the bundled fiber adjacent to the elements of the receiving aperture C irradiates the illumination light and the processing apparatus 6 acquires photoacoustic signals

(electrical signals) from the elements of the receiving aperture C in synchronization with the irradiation. Further, in a time period between the laser emission and the next laser emission, the control apparatus 6a operates the switching unit 8 so that the emitting end 3a of the bundled fiber adjacent to the elements of the receiving aperture D irradiates the illumination light and the processing apparatus 6 acquires photoacoustic signals (electrical signals) from the elements of the receiving aperture D in synchronization with the irradiation. Thereby, photoacoustic signals can be acquired from the apertures of all the elements of the probe 2. When acquiring the photoacoustic signals a plurality of times, in a time period between the laser emission and the next laser emission, the control apparatus 6a operates the switching unit 8 so that the emitting end 3a of the bundled fiber adjacent to the elements of the receiving aperture A irradiates the illumination light and the processing apparatus 6 acquires photoacoustic signals (electrical signals) from the elements of the receiving aperture A in synchronization with the irradiation, and the above operations are repeatedly performed.

[0040] The switching of the emitting end 3a of the bundled fiber and the order of the receiving aperture A to the receiving aperture D described above are not limited to

those described above, and the illumination light only has not to be emitted continuously from the same emitting end 3a of the bundled fiber. For example, the photoacoustic signals (electrical signals) may be acquired first by using the receiving aperture C, and thereafter the photoacoustic signals (electrical signals) may be acquired by using the receiving aperture A, the receiving aperture D, and the receiving aperture B sequentially. Further, the number of the elements of the probe 2, the number of the channels of the processing apparatus 6, a delay time of the synchronization timing, and a receiving time can be changed.

[0041] In a time period from when the photoacoustic signals are received to when the next laser is emitted, an ultrasonic image may be acquired.

[0042] Next, the switching apparatus 8 will be described with reference to Figs. 3A to 3C, 4A, and 4B. Although, in Figs. 3A, 3B, 4A, and 4B, the receiving aperture width is divided into two sections with respect to the entire width of the elements of the probe 2 for ease of explanation of the switching apparatus 8, of course, the explanation can be applied to a case in which the receiving aperture is divided into four sections as shown in Figs. 1 and 2A. All the illumination optical systems 5 are not shown in Figs. 3A to 3C, 4A, and 4B.

[0043] The switching apparatus 8 shown in Fig. 3A uses a

mirror 8d and an actuator 8c can move the mirror 8d for switching an optical path. To input the illumination light into the light incident end 3b of the bundled fiber shown on side A, the mirror 8d provided on the actuator 8c is driven so that the mirror 8d reflects the illumination light. As shown in Fig. 3B, to input the illumination light into the light incident end 3b of the bundled fiber shown on side B, the mirror 8d provided on the actuator 8c is driven so that the mirror 8d does not interfere with the illumination light. In both cases, the control apparatus 6a controls and drives the actuator 8c on the basis of illumination position information of the side A or the side B. Although, in Figs. 3A and 3B, the receiving aperture is divided into two sections, when the number of the divided sections increases, for example when the number of the divided sections is four, as shown in Fig. 3C, the side A to the side D may be selected and switched by positioning the mirror 8d on the actuator 8c.

[0044] Further, the switching apparatus 8 shown in Fig. 4A uses a polygonal mirror 8a instead of the total reflection mirror 8d. The polygonal mirror 8a is adjusted so that the polygonal mirror 8a rotates in synchronization with a light emission frequency of the light source 4 and the illumination light enters the light incident ends 3b of the bundled fibers on the side A and the side B. When a

switching operation to three or more light incident ends 3b using the polygonal mirror 8a is required, the number of the light incident ends 3b of the bundled fibers is increased and the rotation speed of the polygonal mirror is decreased. To simplify the control, it is desired that the rotation speed of the polygonal mirror 8a is constant, so that the light incident ends 3b of the bundled fibers are arranged around the rotation shaft of the polygonal mirror 8a with the same angle in between.

[0045] In Figs. 3A to 3C and 4A, as methods for switching the optical path, a method for driving the mirror 8d by the actuator 8c and a method that uses the polygonal mirror 8a are described. However, the method for switching the optical path is not limited to those methods. An optical element such as a galvanometer mirror and an acousto-optical deflection element (AOD) can be applied to the switching apparatus 8.

[0046] As shown in Fig. 4B, the switching apparatus 8 may use a method in which a plurality of light sources are used, light emission operation timing is adjusted on the basis of the illumination position information from the control apparatus 6a not shown in the drawings, and the irradiation position is switched. In this case, an operation timing control unit may be provided separately or the control apparatus 6a may have the function of controlling the

operation timing. When using the configuration shown in Fig. 4B, a light source 4 having a relatively low total light quantity can be used, so that it is possible to downsize the photoacoustic apparatus.

[0047] The switching apparatus 8 may have a configuration obtained by combining the configurations described with reference to Figs. 3A, 3C, 4A, and 4B. For example, when dividing the receiving aperture into four sections, a switching apparatus having two light sources 4 may be provided as shown in Fig. 4B and the two light source systems are further divided into two sections as shown in Figs. 3A and 3B to obtain four sections in total.

[0048] As described above, according to the configuration described in the first embodiment, the intensity of the photoacoustic signals is increased by irradiating the substantial total light quantity from the light source 4, so that the SNR is improved without increasing the scale of the circuit of the processing apparatus 6, which is the receiving unit, and without increasing the output of the light source 4. Therefore, compared with a case in which the emitting ends are provided in approximately the same width as the width of the elements of the probe 2 in a direction in which the elements are aligned, the light quantity that contributes reception increases corresponding to the division of the receiving aperture, so that, for

example, when dividing the receiving aperture into four sections, the intensity of the photoacoustic waves generated from the subject quadruples. When imaging the photoacoustic signal which is an electrical signal based on the photoacoustic waves, the contrast resolution is improved and the legibility and the diagnosability in clinical practice are improved.

Second Embodiment

[0049] In the first embodiment, the method in which a plurality of emitting ends 3a of the bundled fibers adjacent to the receiving apertures are provided and emitting positions of the illumination light are switched by the receiving apertures. In the second embodiment, a method in which one emitting end 3a of the bundled fiber is used and the emitting end 3a scans according to the receiving aperture will be described with reference to Fig. 5. Description of the same reference signs as those in the first embodiment will be omitted.

[0050] The emitting end 3a of the bundled fiber is adjacent to the probe 2. Although a linear probe is used as the probe 2, it is not limited to this, but a convex probe may be used as the probe 2. In the same manner as in the first embodiment, the substantial total light quantity generated from the light source 4 is maintained and propagated to the emitting end 3a of the bundled fiber. The

area of the emitting end 3a (irradiation area to the subject) of the bundled fiber is determined by a product of the receiving aperture width and the depth in a direction perpendicular to the receiving aperture width. The depth is reduced according to the substantial total light quantity from the light source 4 so that the light quantity increases as much as possible within a range smaller than or equal to the MPE. Thereby, the size of the photoacoustic waves for one time irradiation of the illumination light becomes maximum. The width of the emitting end 3a corresponds to the receiving aperture width.

[0051] Even when the number of elements of the probe 2 is 128 and the number of channels through which the processing apparatus 6 can acquire electrical signal is 32, the present embodiment may be applied by dividing the elements into smaller aperture widths (for example, 8 sets of 16 elements). This is suitable when the output of the light source 4 is low.

[0052] The switching apparatus 8, which is a part of the irradiation control unit, is provided to change the irradiation position of the illumination light. Fig. 5 shows a diagram of the switching apparatus 8 that causes the emitting end 3a of the bundled fiber to scan. The switching apparatus 8 causes the emitting end 3a of the bundled fiber to scan on the basis of the switching information from the

control apparatus 6a (a part of the irradiation control unit) in the processing apparatus 6. The control apparatus 6a causes the switching apparatus 8 to operate so that the emitting end 3a is positioned at a position adjacent to the receiving aperture (a part of transducers of a plurality of transducers) of the probe 2.

[0053] Next, a control method of the control apparatus 6a will be described with reference to Fig. 6. Fig. 6A is a front view of a photoacoustic probe. Fig. 6A schematically shows variation of the light irradiation position (that is, the position of the emitting end) and the position of the receiving aperture. Fig. 6B shows the operation control of the control apparatus 6a.

[0054] As shown in Fig. 6B, when acquiring nth photoacoustic signal (an electrical signal outputted based on the photoacoustic waves), the irradiation position of the illumination light is set to the receiving aperture of the probe 2 so that the irradiation position of the illumination light corresponds to the receiving position of the nth photoacoustic signal, and the photoacoustic signal is acquired. Then, the receiving aperture of the probe 2 and the irradiation position of the illumination light scan an acquisition area of (n+1)th photoacoustic signal. Although, in Fig. 6B, the irradiation position is switched 50 μ sec after the laser light is emitted, the irradiation position

may be switched in a time period from when n th laser light is emitted to when $(n+1)$ th laser light is emitted.

[0055] Although, in the second embodiment, a mechanism in which the switching apparatus 8 scans is employed, it is not limited to this. For example, as shown in Fig. 7, a method can be used in which the illumination light emitted from the bundled fiber not shown in Fig. 7 scans the irradiation position of the illumination light by a reflective element such as a polygonal mirror 8a. In this case, reflective ends of the polygonal mirror 8a are the emitting ends. In this case, it is desired that a beam shaping optical system 8b including a convex lens and an F θ lens is provided.

[0056] According to the configuration described in the second embodiment, an irradiation end of the light can scan continuously with respect to the aperture position and the subject. Therefore, it is possible to receive a photoacoustic signal at any receiving aperture.

Third Embodiment

[0057] In the first embodiment and the second embodiment, the photoacoustic apparatuses in which a linear probe or a convex probe is used as the probe 2 are described. In the third embodiment, a configuration and a method of a photoacoustic apparatus in which a linear probe performs mechanical sector scan in an elevation direction and a three-dimensional image can be acquired will be described.

The configuration of the entire apparatus is the same as that shown in Fig. 1. The features of the photoacoustic probe 1 are shown in Fig. 8.

[0058] Fig. 8 is a front view of the photoacoustic probe 1 in which the linear probe in the probe 2 performs mechanical sector scan in the elevation direction while scanning electronically and which can acquire a three-dimensional image. The control apparatus 6a causes the linear probe in the probe 2 to perform mechanical sector scan in the elevation direction on the basis of the processing apparatus 6. According to the direction of the sector scan, that is, the direction of the receiving aperture, the illumination light is irradiated from the emitting end 3a of the bundled fiber sequentially from the left side (side A) to the right side (side B) of Fig. 8. The above operation may also be applied to a case in which a two-dimensional array type probe 2 performs electronic sector scan. The configuration and method described in the first embodiment with reference to Figs. 3A to 3C or Figs. 4A and 4B may be applied to the switching operation in this case.

[0059] As described above, in the method in which the emitting position of the illumination light is controlled according to the receiving direction of the photoacoustic waves, the illumination light can be irradiated from a position according to the sector scan direction (direction

of the receiving aperture). Therefore, the improvement of the SNR by increasing the receiving sound pressure as much as possible can be applied to the probe 2 that can acquire a three-dimensional image.

[0060] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0061] This application claims the benefit of Japanese Patent Application No. 2011-113907, filed May 20, 2011, which is hereby incorporated by reference herein in its entirety.

CLAIMS

[1] A subject information acquisition apparatus comprising:

a light irradiation unit including a light source and an emitting end portion configured to emit light generated by the light source to a subject;

an irradiation control unit configured to control irradiation of the subject with the light emitted from the emitting end portion of the light irradiation unit;

a probe including a plurality of transducers configured to receive acoustic waves generated by the subject irradiated with the light from the light irradiation unit and output electrical signals;

a receiving unit configured to receive the electrical signals from a part of transducers of the plurality of transducers included in the probe; and

a probe control unit configured to switch a part of transducers that output the electrical signals to be received by the receiving unit to another part of transducers,

wherein the irradiation control unit controls a position of the emitting end portion with respect to the subject so that a size of an irradiation area of the light to the subject is smaller than the total size of the transducers and the irradiation area corresponds to a position of the part of transducers while a quantity of the

light emitted from the emitting end portion is maintained at a total light quantity of the light generated by the light source.

[2] The subject information acquisition apparatus according to Claim 1, wherein the light irradiation unit includes a plurality of the emitting end portions and the irradiation control unit emits light from a part of emitting end portions of the plurality of emitting end portions and switches the part of emitting end portions that emit light to control a position of the emitting end portions with respect to the subject.

[3] The subject information acquisition apparatus according to Claim 2, wherein the probe further includes a sector scan unit configured to perform sector scan on the transducers, the plurality of emitting end portions are located with the probe sandwiched in between, and the irradiation control unit switches the part of emitting end portions that emit light of the plurality of emitting end portions on the basis of an operation of the sector scan unit to control the position of the emitting end portions with respect to the subject.

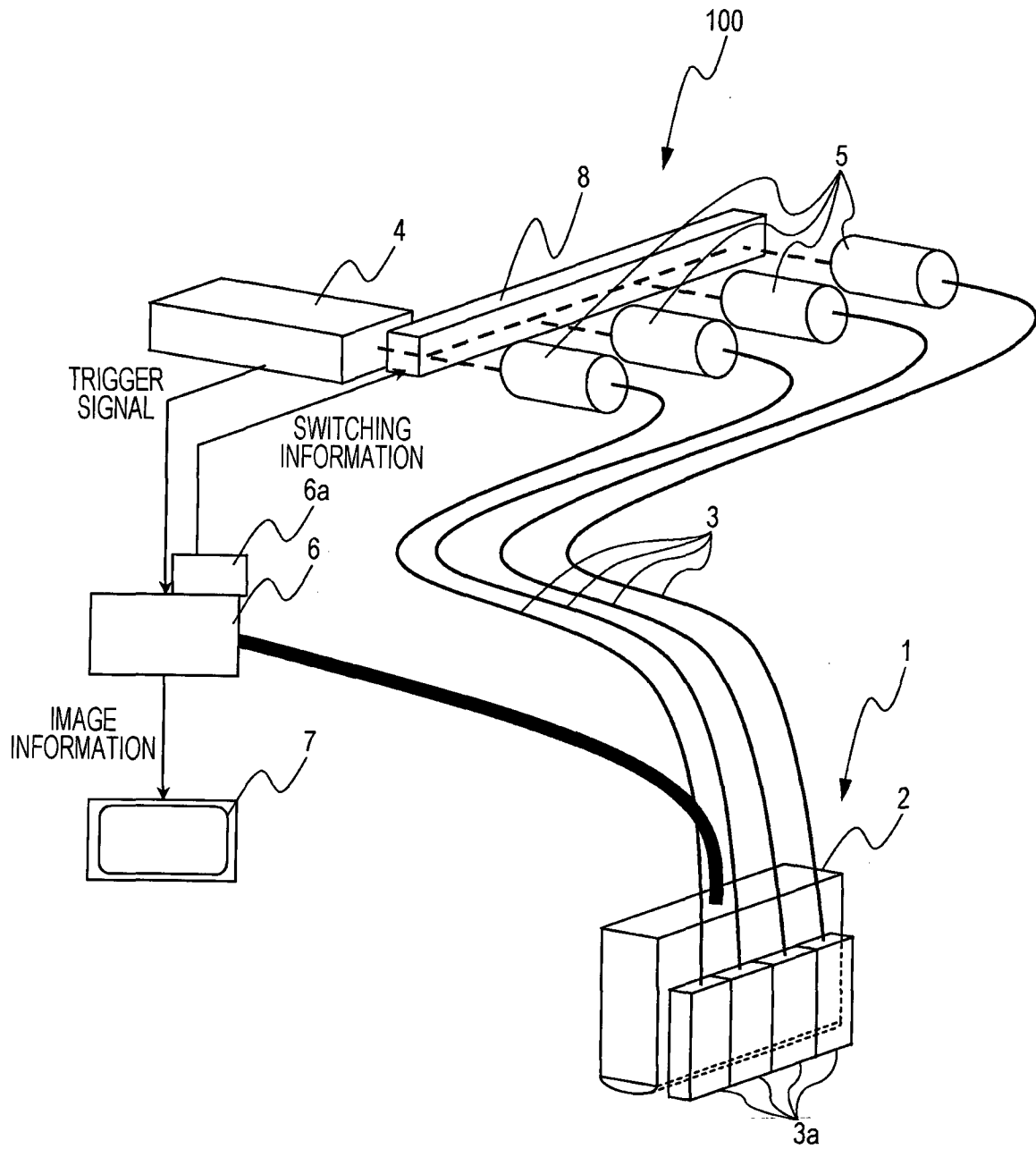
[4] The subject information acquisition apparatus according to Claim 1, wherein an irradiation control unit scans the emitting end portion to control a position of the emitting end portion with respect to the subject.

[5] The subject information acquisition apparatus according to any one of Claims 1 to 4, wherein the size of the irradiation area is almost the same as that of the part of transducers.

[6] The subject information acquisition apparatus according to any one of Claims 1 to 5, wherein the light irradiation unit includes a plurality of light sources and further includes a timing control unit configured to control operation timing of the plurality of light sources.

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FIG. 1



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FIG. 2A

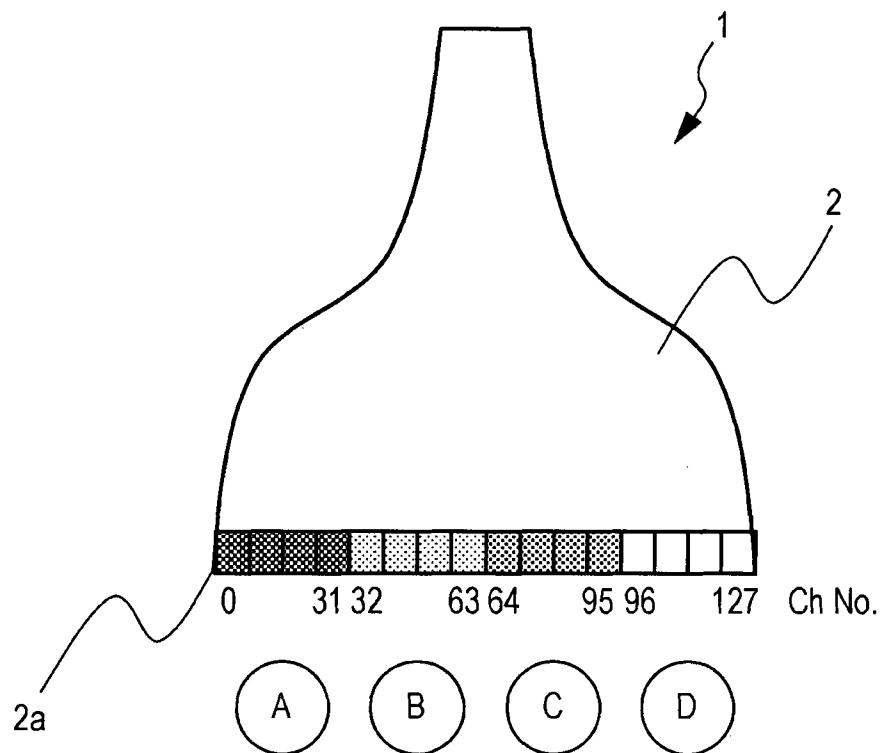
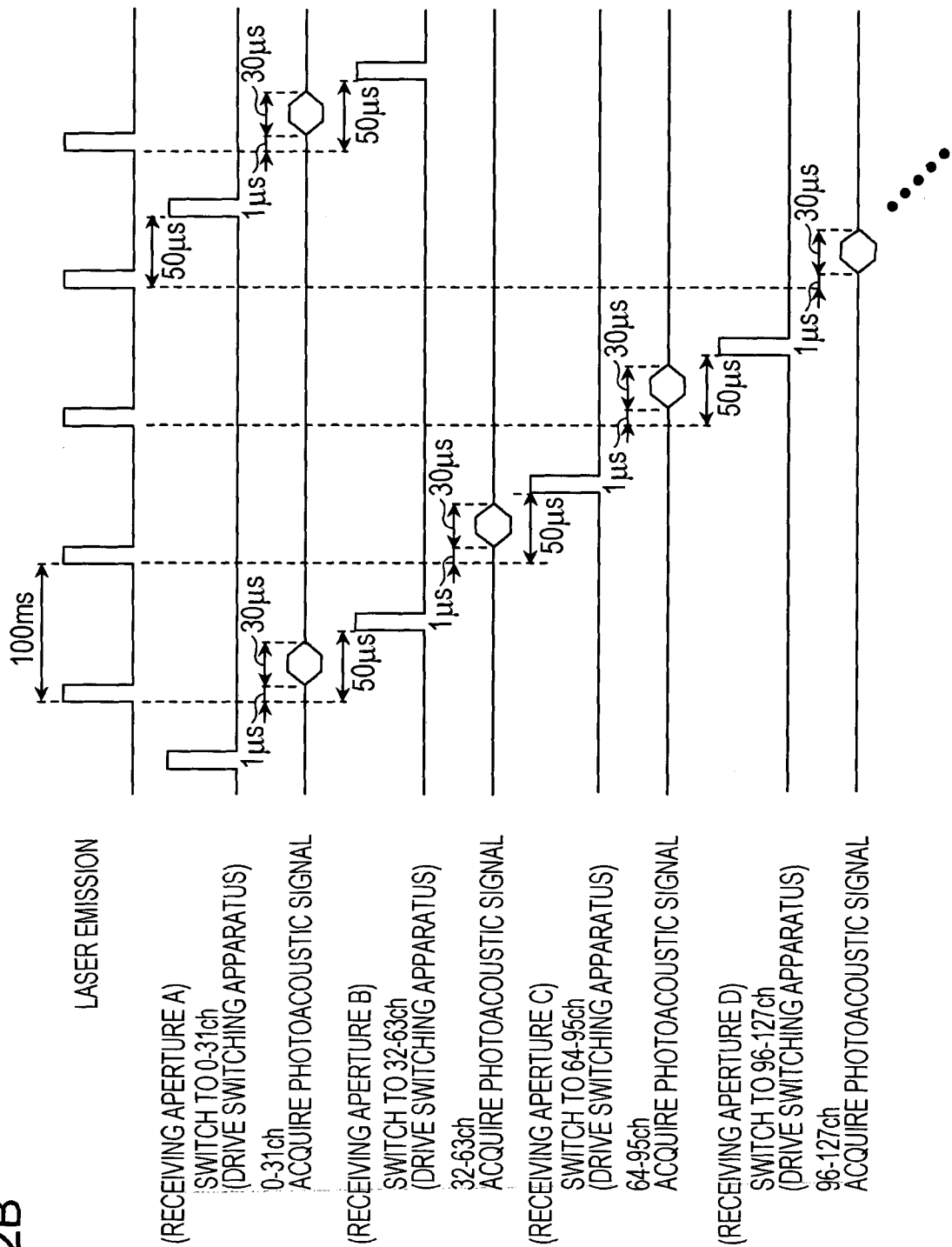


FIG. 2B



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FIG. 3A

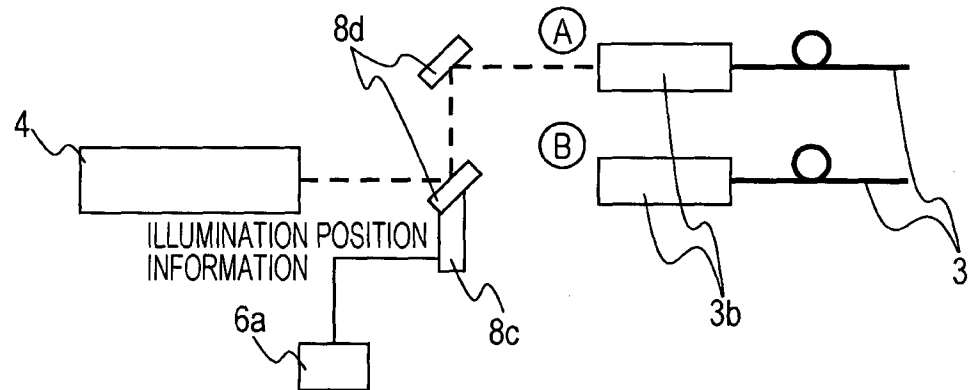


FIG. 3B

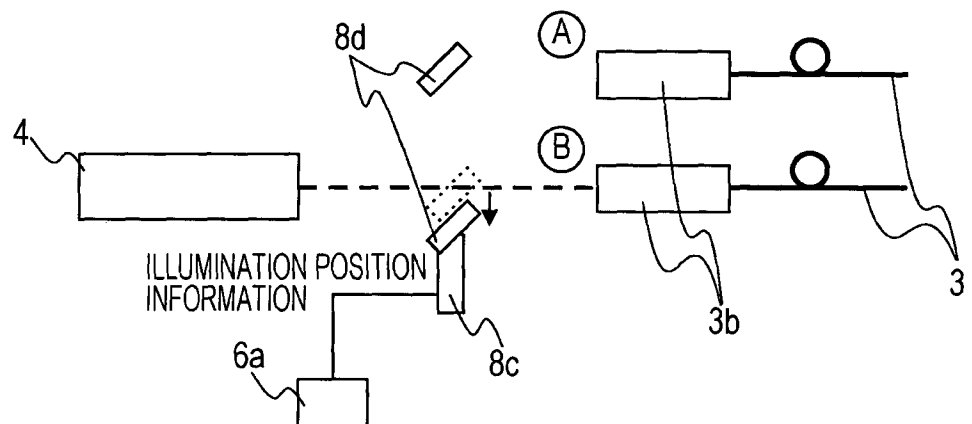
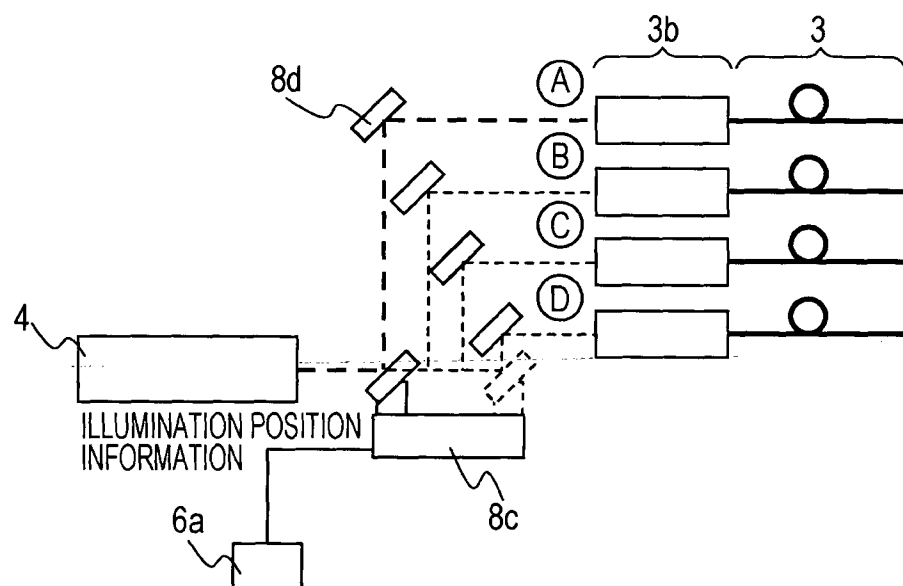


FIG. 3C



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FIG. 4A

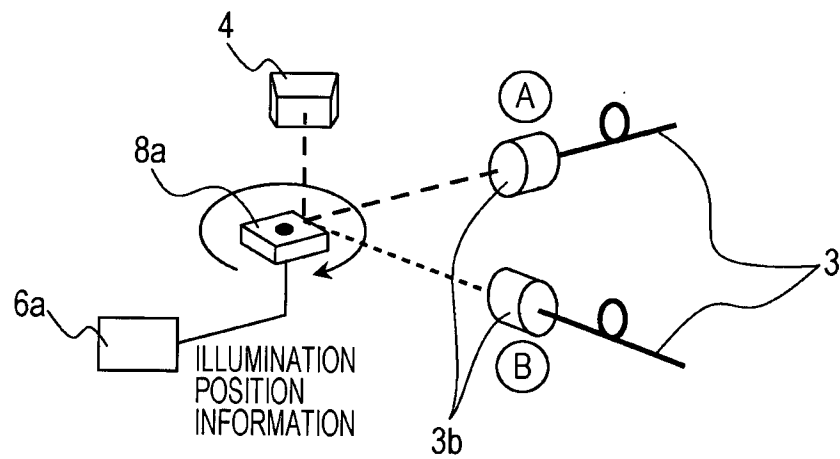
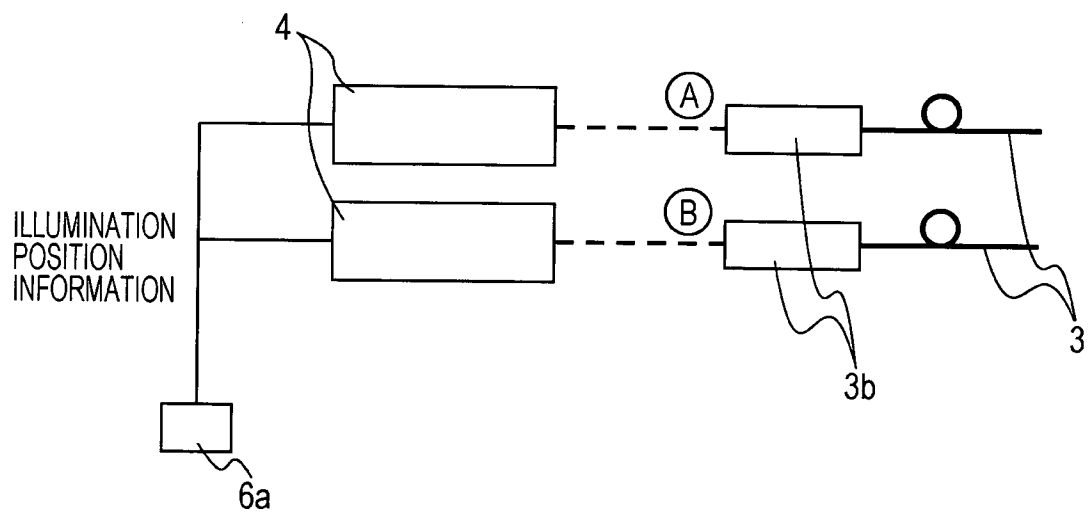
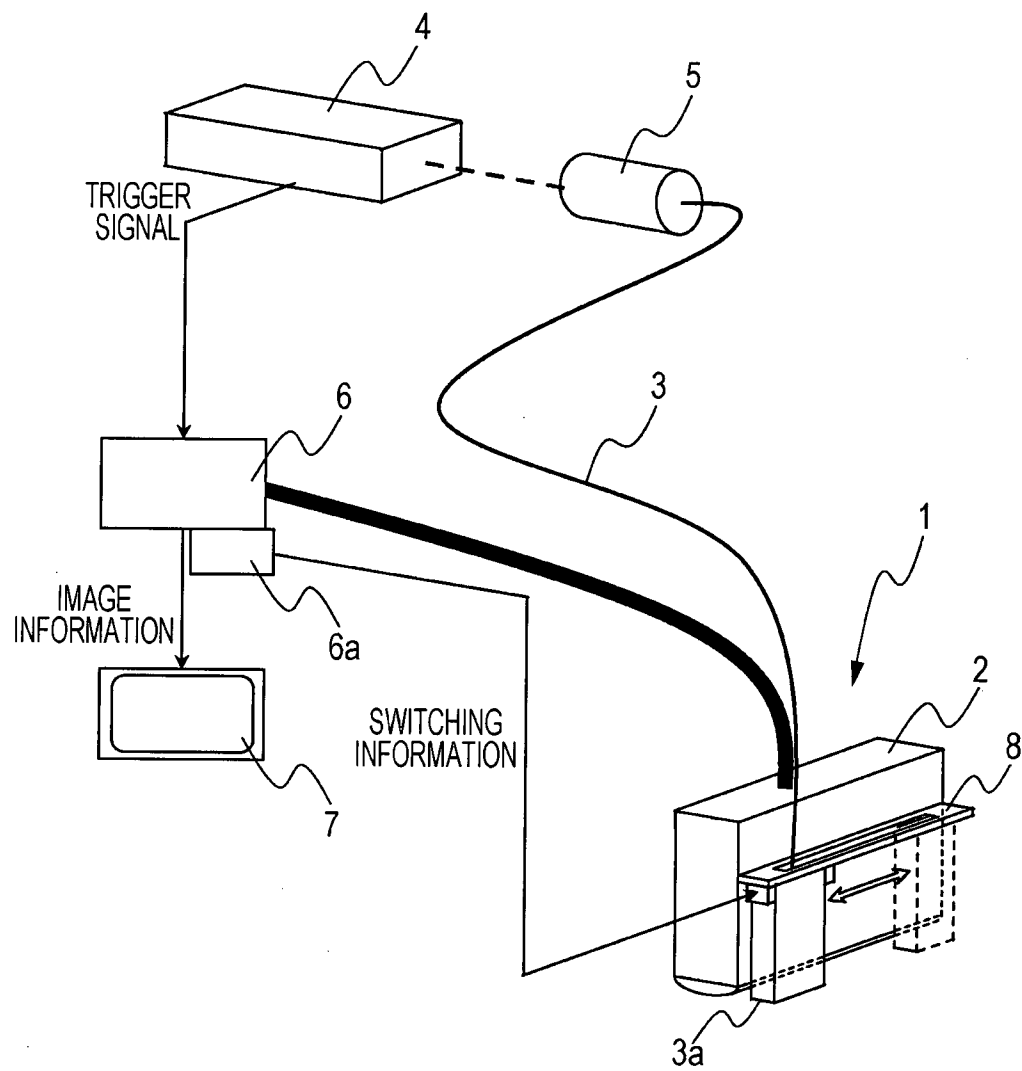


FIG. 4B



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FIG. 5



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FIG. 6A

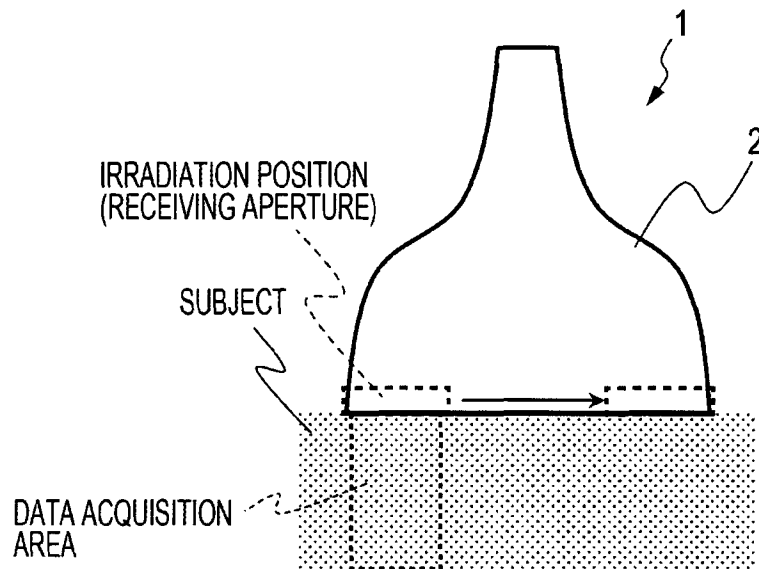
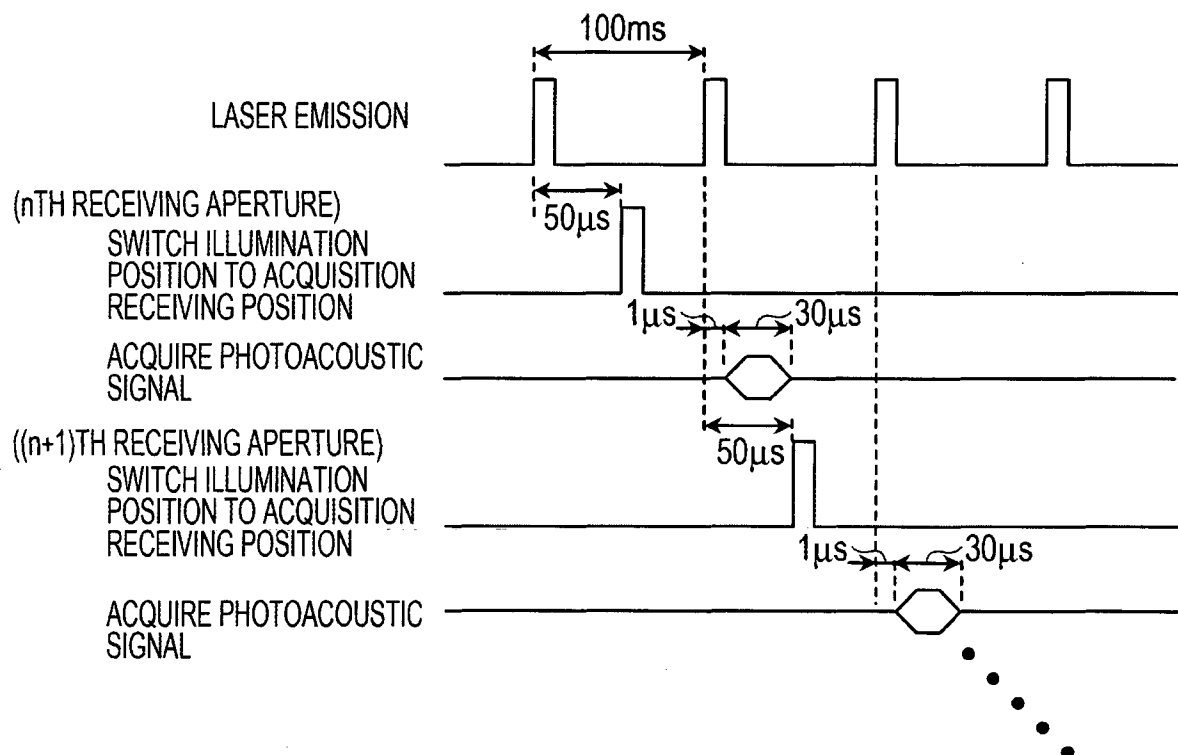
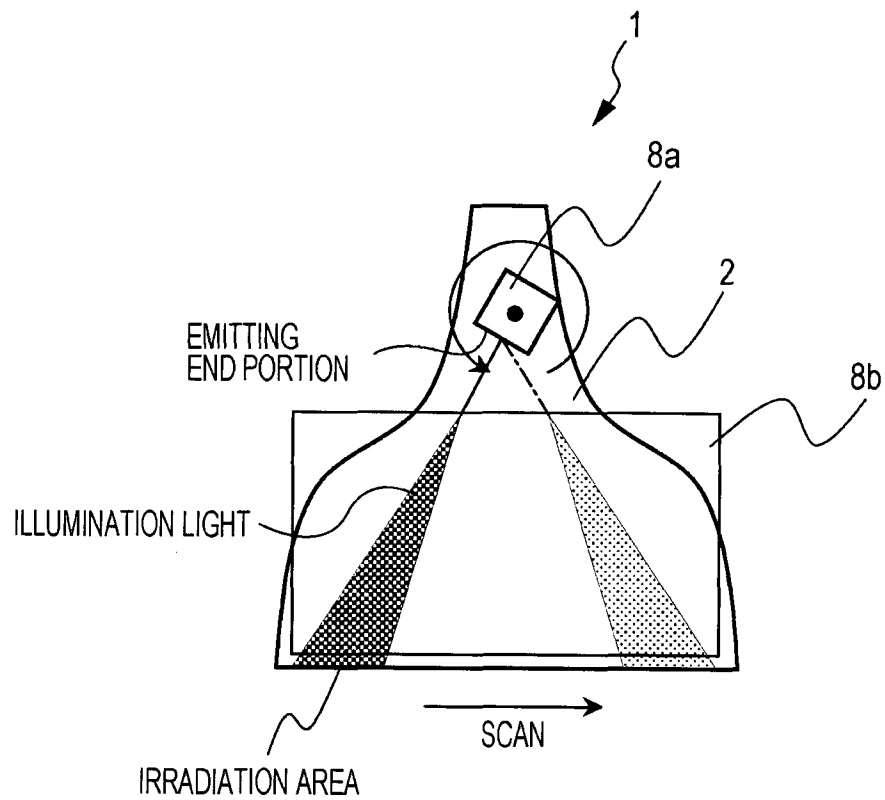


FIG. 6B



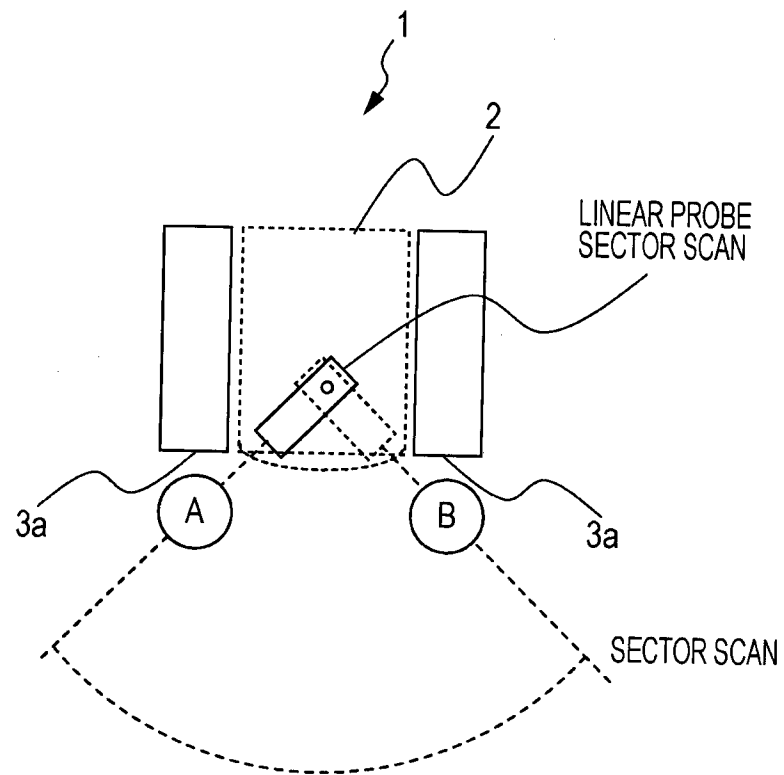
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FIG. 7



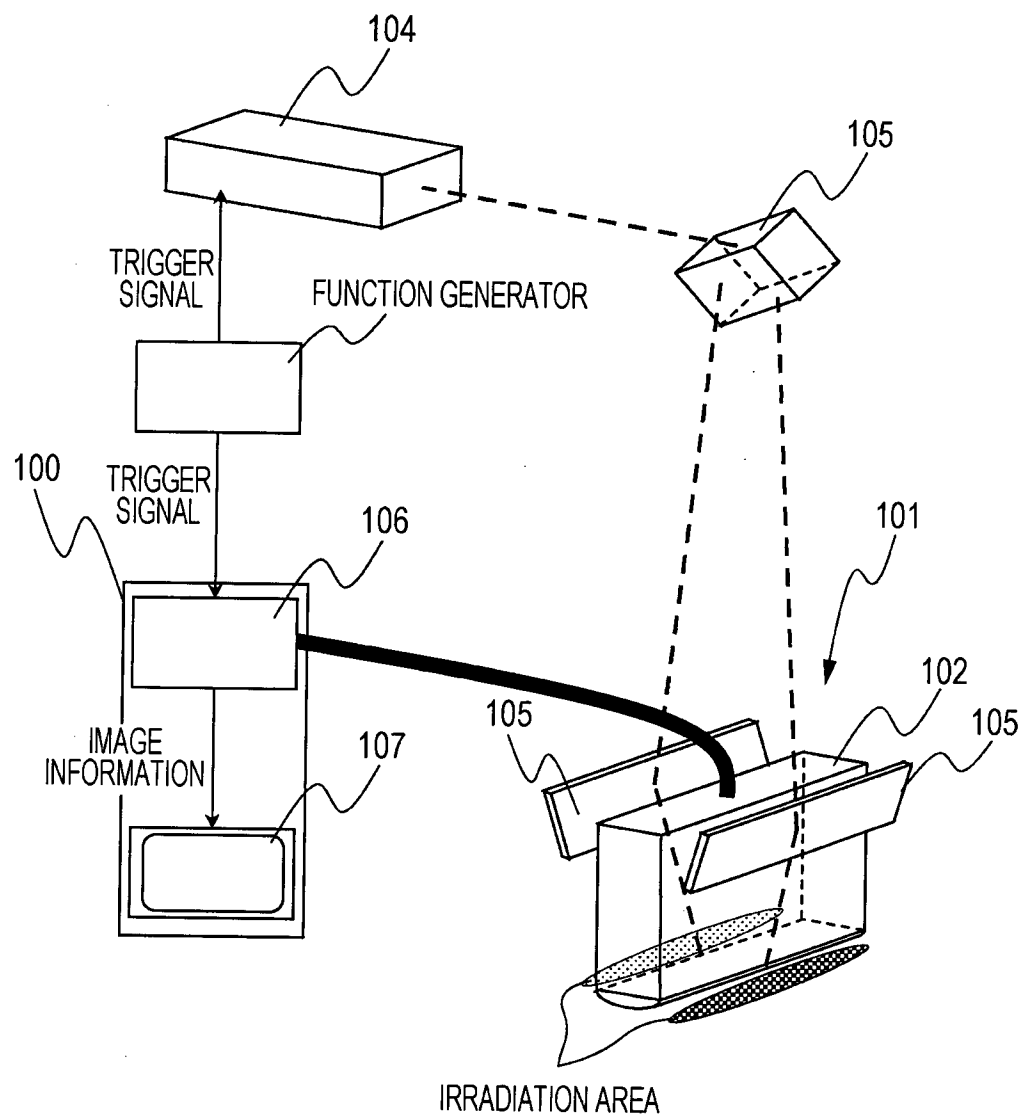
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FIG. 8



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FIG. 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2012/062729

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/00 G01N21/17 G01N29/24
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

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X	WO 2004/042382 A1 (ABBOTT LAB [US]; TOSHIBA KK [JP]; KANAYAMA SHOICHI [JP]; ITSUMI KAZUHI) 21 May 2004 (2004-05-21) pages 9-10 pages 12-15, pages 17-19; claims; figures -----	1-6
X	WO 2006/061829 A1 (GLUCON INC [US]; PESACH BENNY [IL]; NAGAR RON [IL]; BITTON GABRIEL [IL]) 15 June 2006 (2006-06-15) page 12 - page 14; claims; figures ----- -/-	1-5



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

15 August 2012

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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International application No

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